Chapter 8

Assessment of Wildfire Exposure to Public Water Supply Areas in Oregon

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Photo: USDA Forest Service

The cause of recent wildfire catastrophes can be traced to multiple factors, including the expanding urban footprint (Radeloff et al. 2018), human ignitions (Nagy et al. 2018), droughts (Littell et al. 2016) and high-wind events (Abatzoglou et al. 2018). In 2018, over 58,000 wildfires burned 8.8 million acres in the western U.S. (NIFC 2018). As wildfire frequency and intensity increase (Westerling 2016, Abatzoglou et al. 2017), understanding the impacts of high-severity wildfire on ecosystem function is critical, particularly the negative effects on soils (Certini 2005) and drinking water source areas (Robinne et al. 2019).

8.1. Introduction

Wildfires remove litter, duff and vegetative cover, leading to the creation or enhancement of hydrophobic soil layers, increasing surface runoff and erosion potential (Beyers et al. 2005, Larsen et al. 2009, Robichaud and Ashmun 2013). Large and severe wildfires can occur at the watershed scale and affect hydrologic processes, including changes in stream flow, flood frequency, erosion and sedimentation (Beyers et al. 2005, Smith et al. 2011). Postfire changes in water chemistry and sediment transport can increase pollutant loads, with significant consequences for human health, safety and aquatic habitats (Morrison and Kolden 2015, Nunes et al. 2018, Rust et al. 2018, Hohner et al. 2019). In 2017 the Eagle Creek Fire east of Portland started in the Columbia River Gorge, burned over 48,000 acres and took three months to contain. It burned within one mile of the Bull Run Watershed that supplies drinking water to 1 million people within the Portland metropolitan area. The intensity of these effects are in turn related to burn severity, soil characteristics, topography, fuel type and postfire weather conditions (Certini 2005, Shakesby and Doerr 2006).

The growing awareness of the expanding scale of wildfire risk to communities, watersheds and water supplies in the U.S., has led to a wide range of research focused on fuel treatments to reduce postfire impacts to watersheds and drinking water. At the same time watershed investment programs are being initiated in the western United States to address wildfire risk to municipal water (City of Ashland 2019, FWPP 2019). Researchers are using wildfire simulation models to test hypothetical treatment scenarios and estimate the potential reduction in risk as measured by metrics that measure adverse impacts, including soil erosion (Elliot et al. 2016, Jones et al. 2017) and change in water yield (Srivastava et al. 2018). Typically, soil-burn severity is quantified using gridded flame length outputs from fire models (Elliot 2016). These can be cross-walked to erosion prediction models like the watershed erosion prediction project and existing geospatial data on potential fire effects (Miller et al. 2011, Flanagan et al. 2013). Financial analyses that compare the cost of fire mitigation to water supplies have shown both positive (Jones et al. 2017) and negative (Gannon et al. 2019) rates of return from fuel management programs depending on assumptions about fire occurrence. Wildfires are relatively rare, and using risk frameworks that incorporate probabilistic expected impacts (versus conditional that a fire occurs) undermines the cost-benefit analyses unless other values can be included in rate of return investment schemes, including avoided suppression costs, wildlife habitat, ecological restoration, recreation and public safety (Gannon et al. 2019). Typically the fuel treatment studies that examine water issues are restricted to a watershed but now can be scaled up over large areas of the West using geospatial data on potential postfire erosion rates for forests and shrublands (Miller et al. 2011). This latter work was completed by the disturbed watershed erosion prediction project using the GeoWEPP model (Renschler 2003).

Several new forest management authorities are being implemented that motivate increasing the scale of activities that span jurisdictions and landowner boundaries (USDA Forest Service 2018). These include authorizing legislation, such as the good neighbor authority (2015), the 2014 Farm Bill and the recent shared stewardship program (USDA Forest Service 2018). In turn, the growing emphasis on cross-boundary management of wildfire issues has motivated the research community to expand risk frameworks that are fine-tuned to meet the needs of new authorizing legislation (Ager et al. 2018, Ager et al. 2019a, Ager et al. 2019b). ***For instance, existing risk assessment technologies and frameworks do not explicitly examine the cross-boundary problem intrinsic to wildfire risk from large public wildlands*** (WWWRA 2013, Dillon et al. 2014). Most risk assessments simply measure in situ risk, without a linkage to the source of large fires that typically start in wildlands long distances from developed areas and the sources of

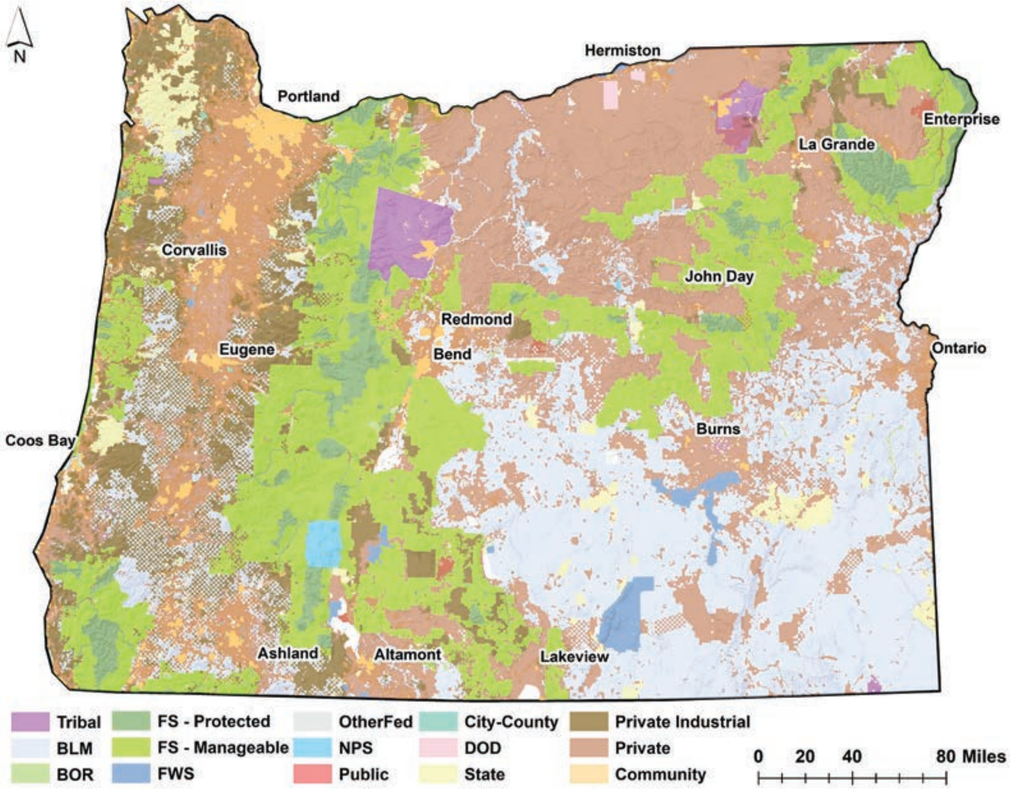


Figure 8-1. Land tenures in Oregon based on the Protected Areas Database (USGS 2016) and Pacific Northwest timberland ownership (Atterbury Consultants 2017). Figure from Day et al. (2018).

water they are dependent on (Robinne et al. 2018, Robinne et al. 2019). Clearly, in an era where the scale of risk is rapidly expanding with larger and larger fires, it is important to understand topological properties of cross-boundary fire on landscapes fragmented by ownership and jurisdictions.

In this report, we first summarize methods used to assess wildfire exposure and transmission and then provide a detailed assessment of cross-boundary wildfire exposure in Oregon between major land tenures (private, public, state and federal) and drinking water source areas. The goal of the work is to provide decision-support information to public and private fire-mitigation programs. The outputs from this study can be used to prioritize cross-boundary, shared-stewardship projects aimed at reducing fire exposure to drinking water.

8.2. Methods

8.2.1. Wildfire risk versus exposure

Wildfire risk concerns the estimation of expected loss, calculated as the product of the likelihood of a fire at a given intensity and the consequences. By contrast, wildfire exposure concerns the juxtaposition of threatened values in relation to predicted fire occurrence and intensity, without estimating potential loss (SRA 2006). In this assessment we focus on wildfire exposure to reduce complexity and not bias the results with assumed loss functions that have high levels of uncertainty in terms of fire effects on public water supply areas.

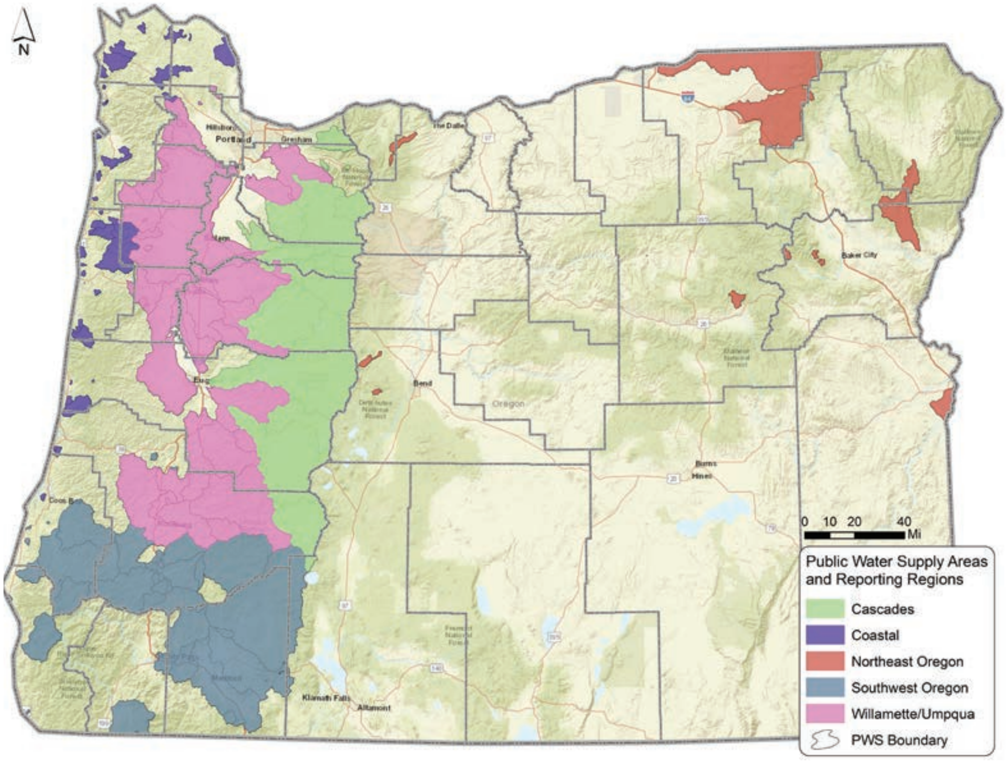


Figure 8-2. Public water supply areas and reporting regions used in data analysis.

8.2.2. Study area and land tenure assignment

The study area included more than 150 land tenures in Oregon, grouped in 15 major classes derived from the Protected Areas Database of the United States (USGS 2016), and updated with private land tenure information from Pacific Northwest timberland ownership (Atterbury Consultants 2017) (Figure 8-1). The three largest major land tenures were the U.S. Forest Service-administered land (15.6 million acres), the Bureau of Land Management (15.8 million acres) and private (nonindustrial) land (20.3 million acres).

To assess cross-boundary exposure to public water supply areas, we divided the study area into public water supply reporting regions, including the Cascades, Coastal, Northeast Oregon, Southwest Oregon and Willamette/Umpqua (Figure 8-2). We included 159 public water supply areas in the analysis, although 19 experienced virtually no wildfire in the simulations.

8.2.3. Wildfire simulations

Data from the wildfire simulation model FSim (Finney et al. 2011; version 2016) were used to predict wildfire exposure within and among the land tenures and transmission into public water supply areas. FSim generates daily wildfire scenarios for a large number of wildfire seasons using relationships between historical Energy Release Component (Bradshaw et al. 1983) and historical fire occurrence. Wildfires are simulated with the minimum travel time (Finney 2002) algorithm under weather conditions derived from time series analysis of historical weather. Weather data were derived from the network of remote automated weather stations located throughout the U.S. (Zachariassen et al. 2003). Fuel models (Figure 8-3), canopy cover and canopy fuel layers were derived from LANDFIRE (2014). FSim outputs include the ignition location of each fire, fire perimeters, grids of burn probability (Figure 8-4) and conditional probabilities by flame

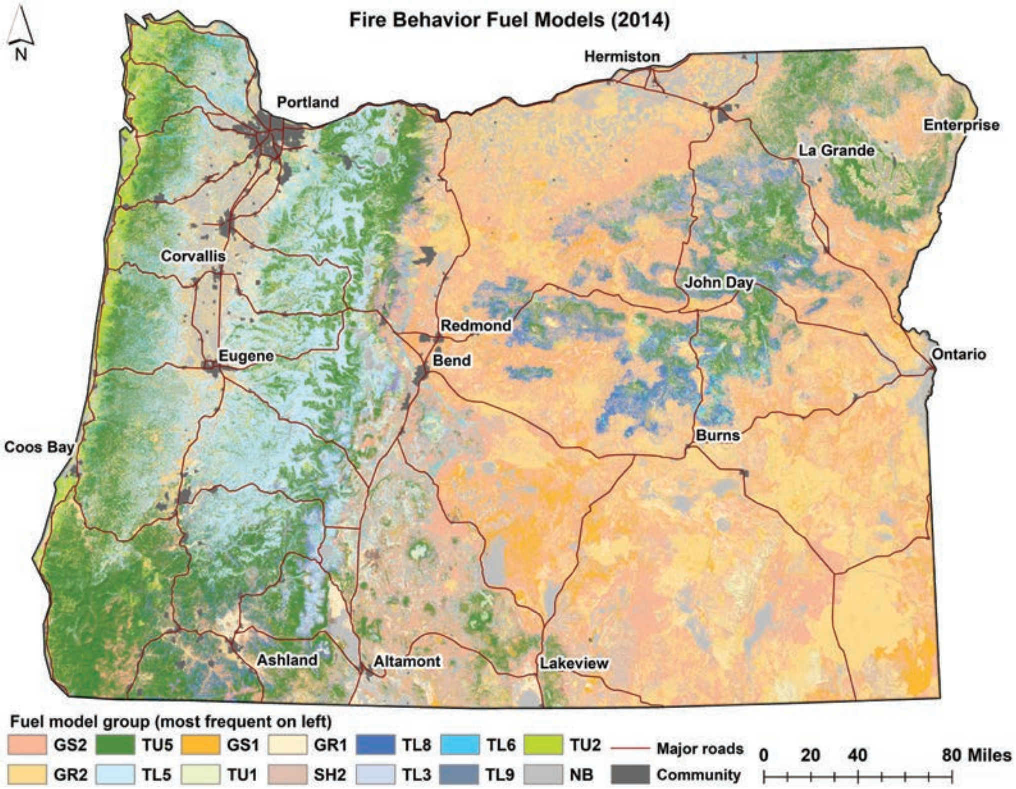


Figure 8-3. Fuel models used in the wildfire transmission analysis were derived from LANDFIRE (2014) based on Scott and Burgan (2005) (Day et al. 2018). Note the LANDFIRE version used in the FSim analysis was 2012.

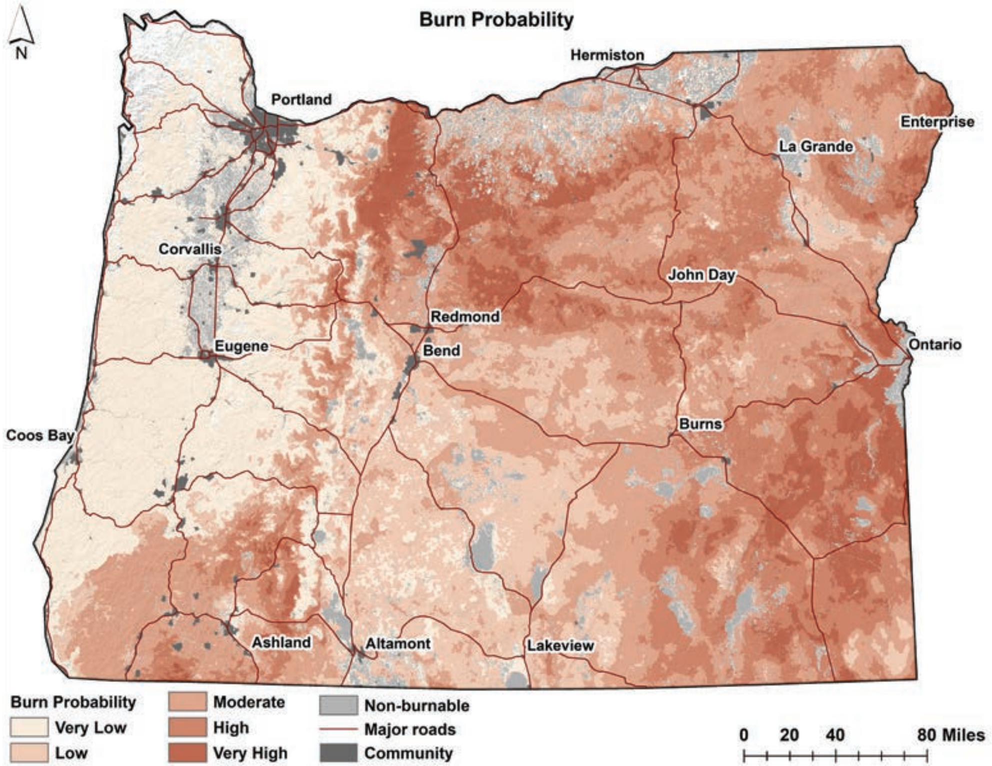


Figure 8-4. Annual burn probability estimated from simulation modeling (Day et al. 2018).

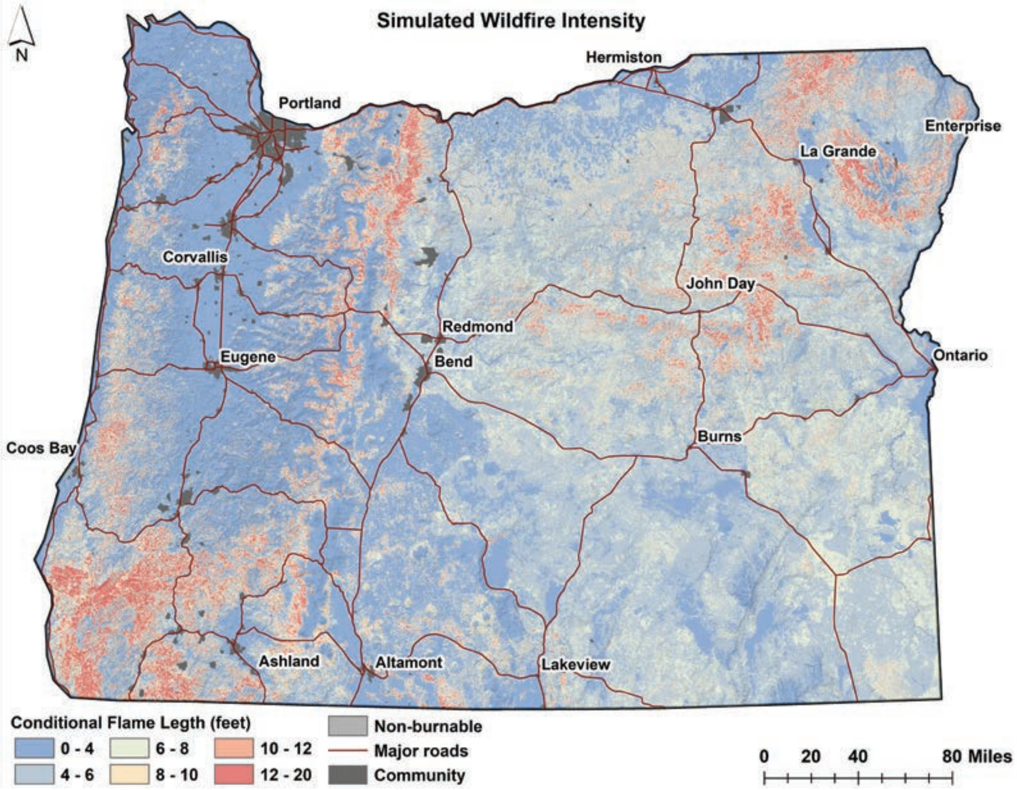


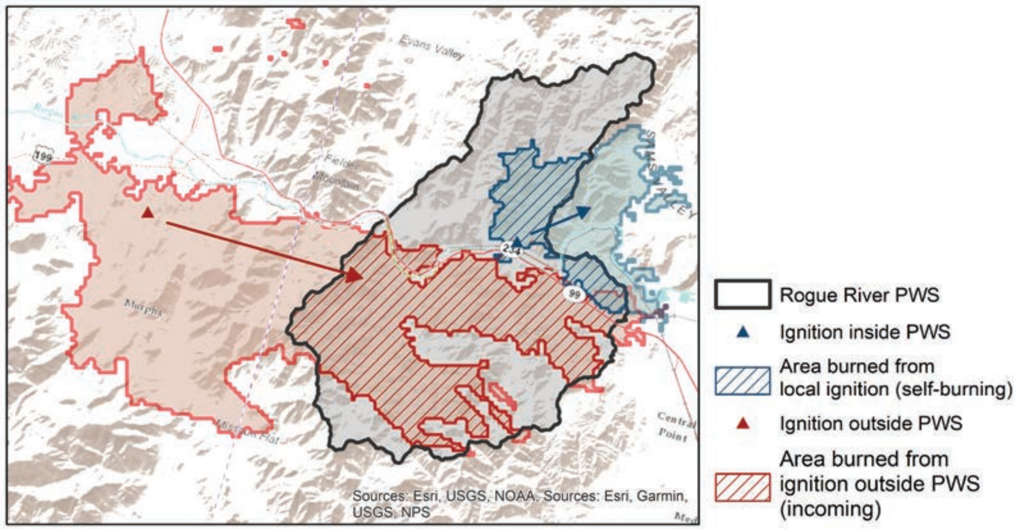
Figure 8-5. Mean flame length or predicted wildfire intensity estimated from simulation modeling (Day et al. 2018). Higher values represent higher potential for crown fire activity.

length category (Figure 8-5). The data used consisted of 1,430,417 ignitions simulated inside and within ca. 5 mi buffer around the public water supply areas layer, representing 10,000 fire season replicates depending on the region (Finney et al. 2011).

We also calculated and mapped two wildfire exposure metrics to illustrate the spatial scale and complexity of wildfire exposure in relation to the geography of land tenure across the state. Each metric was calculated at 1640-by-1640 foot pixel resolution (500 meters). The metrics describe both the scale and composition of fire effects that ignite elsewhere and arrive at a given pixel. The fire size potential index was the average fire size (acres) that was generated by an ignition in each pixel. Here, each simulated fire was attributed to the ignition point and the points smoothed to create a continuous raster coverage. The fire size arrival index measured the average fire size (acres) that burned each pixel.

8.2.4. Quantifying cross-boundary wildfire

Analysis of wildfire transmission was conducted at the public water supply areas and public water supply region scales, similar to the methods described in Ager et al. (2017a) and Ager et al. (2018). Cross-boundary wildfire was quantified by intersecting wildfire perimeters with major land tenures and public water supply areas in Oregon (Figures 8-1 and 8-2). Polygons were dissolved by the major land tenure to avoid a false fragmentation within the same agency or land owner. The origin of each wildfire was assigned based on the point of ignition. Total burned area within each public water supply area was aggregated by incoming fire, outgoing fire, and self-burning or nontransmitted fire. Incoming fire is the area burned of all fires ignited outside the public water supply area and entering each particular public water supply area. Outgoing fire is the area burned



Sources: Esri, USGS, NOAA, Sources: Esri, Garmin, USGS, NPS

Figure 8-6. Cross-boundary fire components for an example public water supply area (PWSA) and example simulated fires. Cross-boundary exposure to PWSAs was calculated by intersecting simulated wildfire perimeters with PWSA boundaries and attributing wildfire exposure to the source land parcel (red triangle represents ignition outside of a PWSA). Arrows indicate direction of fire spread. Wildfires ignited locally are considered self-burning; wildfires ignited outside of the PWS and burning inside are considered incoming.

of all fires ignited in a public water supply area that escapes its boundaries. Self-burning, or non-transmitted, fire is the area burned within a public water supply area by ignitions in the same public water supply area (Figure 8-6). We analyzed wildfire transmission to 1) delineate the areas that send fire into each public water supply area, 2) quantify the ownership breakdown of that contributing area, and 3) assess the fire intensity, frequency and size of the fires burning into each public water supply area. Regional results are presented here, and results by individual public water supply area will be presented in an online atlas.

8.2.5. Fireshed mapping

We used wildfire simulation results to identify the areas where large fires are likely to ignite and expose public water supply areas. These “firesheds” define the biophysical risk containers in and around public water supply areas and the sources of risk in terms of ownership. Firesheds can be further characterized by fire regime and management capability, although this was beyond the scope of the current work. We mapped public water supply area firesheds by creating a continuous smoothed surface of predicted wildfire exposure from all FSim ignitions that resulted in fires that intersected public water supply area polygons. We used inverse distance weighting geostatistical interpolation, implemented through the ArcGIS geostatistical analyst module (ESRI 2013), using a 5-kilometer fixed search radius. In addition to a statewide fireshed map, firesheds were developed individually for each public water supply area and will be available in an online atlas.

8.3. Results

8.3.1. Exposure metrics

We quantified and mapped the scale of wildfire exposure in the study area with the two exposure metrics as described above. The fire size potential index (Figure 8-7) identified locations that generated the largest fires, with the highest values observed for southwestern Oregon and parts of northeastern and eastern Oregon. The fire size arrival index (Figure 8-8) estimated the average size of the fire that burned each pixel, with the highest values again in southwest Oregon but also large areas of central and southeast Oregon.

8.3.2. Predicted wildfire exposure by public water supply area and region

Predicted area burned in 100 years was highest for public water supply areas in the eastern Cascades, southwest Oregon and in eastern Oregon (Figures 8-10 and 8-11; Table 8-1). Mean fire size, total annual area burned and the number of simulated fires that exposed public water supply areas also varied substantially across the regions (Table 8-1) with the largest fires and the highest area burned occurring in southwestern Oregon. The individual public water supply areas with the highest exposure on a percentage basis was the City of The Dalles, although 16% of the public water supply area had no fire exposure and 64% were exposed on less than 1% of their total area (Table 8-2). Although these

Table 8-1. Wildfire exposure to public water supply area (PWSA) regions in Oregon.

PWSA region	Number of simulated fires	Mean fire size (acre)	Total annual area burned (acre)	Percentage burned in 100 years
Southwest	222,652	2,769	12,552	2.0 (0.01–6.4)
Cascades	198,033	1,073	6,593	1.7 (0.02–6.6)
Northeast	59,654	2,717	4,138	5.1 (0.9–17.3)
Willamette/Umpqua	290,574	268	806	0.1 (0–0.88)
Coastal	27,181	440	6	0.01 (0–0.07)

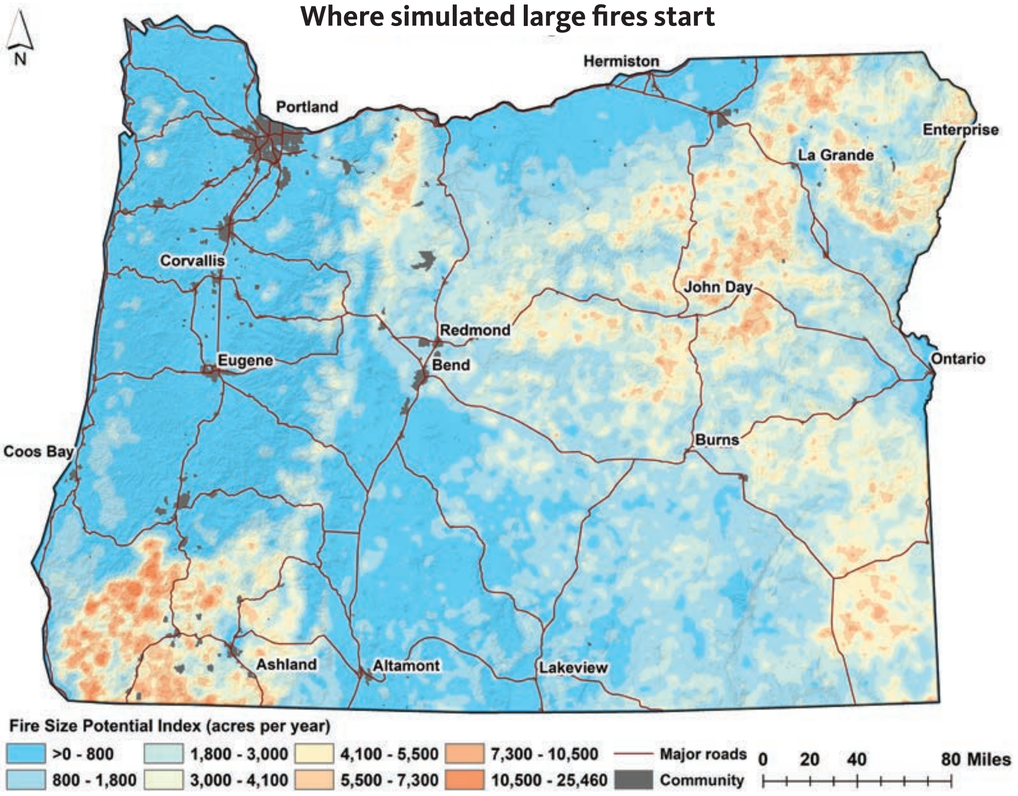

Where simulated large fires start

Figure 8-7. Fire size potential index is the average fire size that was generated by a simulated ignition in a given place and shows the potential fire sources. Figure from Day et al. (2018).

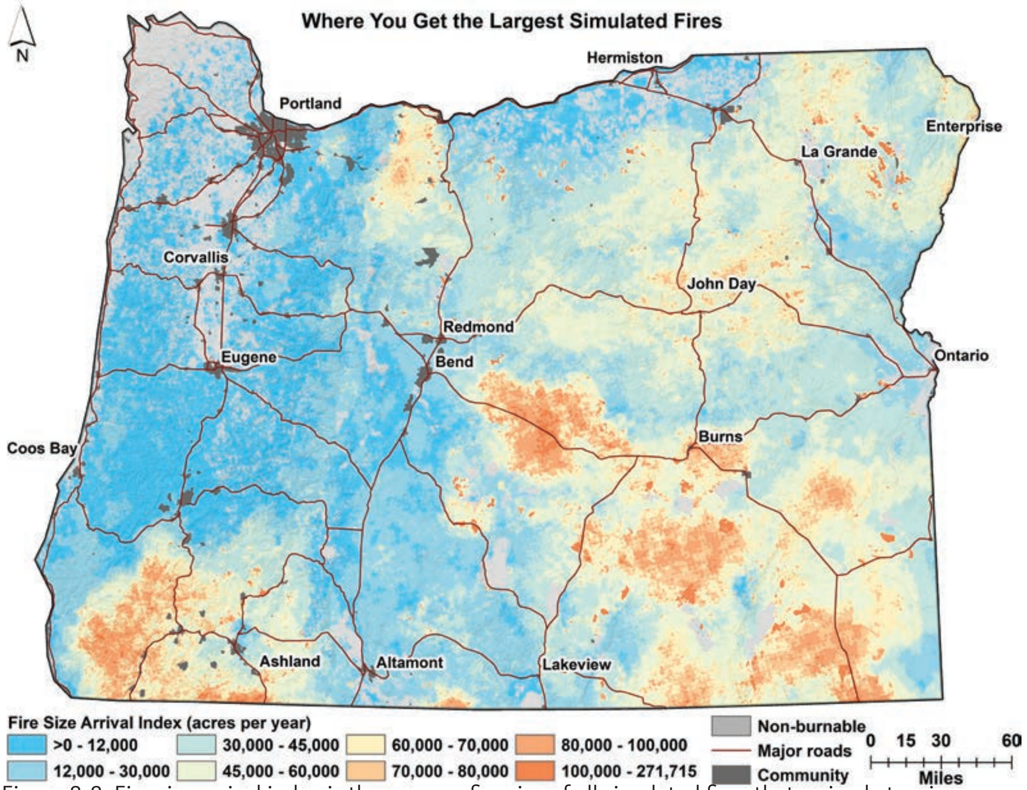


Figure 8-8. Fire size arrival index is the average fire size of all simulated fires that arrived at a given place and shows the areas at risk from large fires (Day et al. 2018).

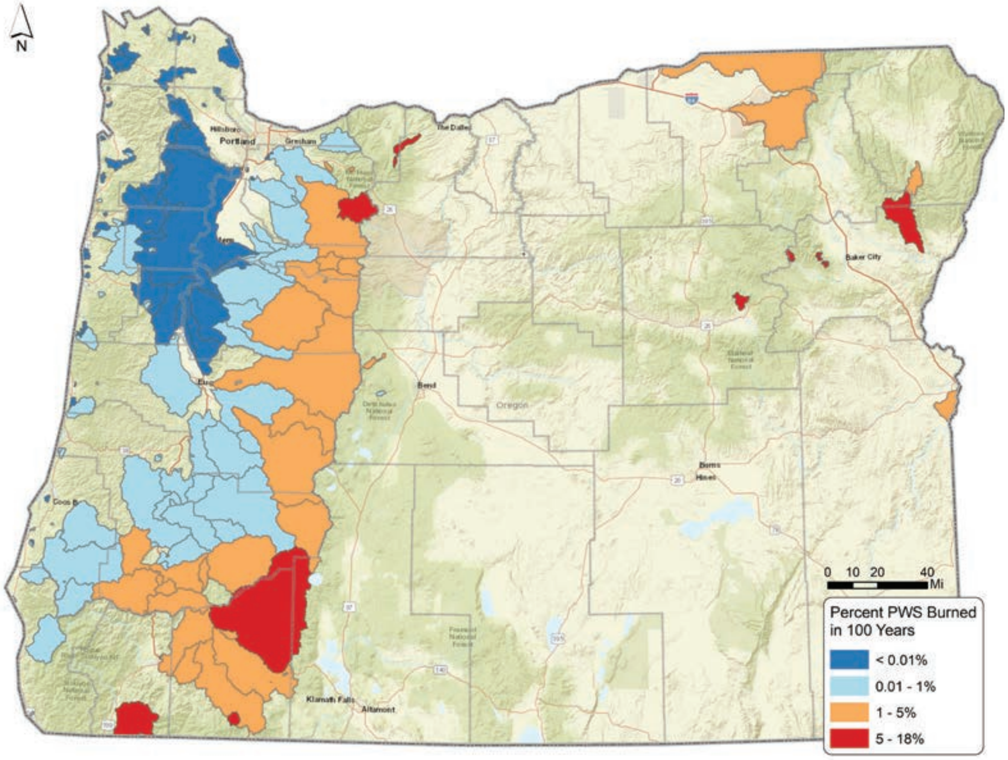


Figure 8-9. Predicted percentage area burned in 100 years of public water supply areas (PWSA) showing the relative differences in PSWA exposure across the state.

Table 8-2. Wildfire exposure as measured by percentage area burned in 100 years for the top 25 public water supply areas (PWS) in Oregon.

PWSA name	Rank	PSWA area (acres)	Area burned in 100 years (acres)	(%)	Number of land tenures contributing to exposure[1]	Largest fire (acres)[2]
City of The Dalles	1	20,560	3,555	17.3	7	290,345
Young Life Wash Family Ranch	2	242	22	9.2	3	185,016
USFS Timber Lake JCC	3	83,672	5,511	6.6	2	248,166
Prairie City	4	15,499	1,006	6.5	4	528,367
Richland, City Of	5	113,940	7,284	6.4	4	311,610
City of Cave Junction	6	148,775	9,490	6.4	7	490,695
City of Sumpter	7	6,723	411	6.1	4	528,367
Baker City	8	6,843	411	6.0	5	232,739
Country View MH Estates	9	734,026	42,930	5.8	7	312,358
Ashland Water Department	10	12,736	644	5.1	5	598,588
City of Grants Pass	11	170,960	8,340	4.9	7	521,502
Breitenbush Hot Springs	12	35,722	1,701	4.8	4	145,679
City of Pendleton	13	283,054	13,182	4.7	6	338,577
Medford Water Commission	14	289,951	13,282	4.6	7	312,358
City of Rogue River	15	69,007	3,022	4.4	6	521,502
City of Glendale	16	119,381	5,137	4.3	7	521,502
City of Canyonville	17	22,657	930	4.1	6	521,502
USFS Tiller Ranger Station	18	288,523	11,675	4.0	4	237,655
Angler’s Cove/SCHWC	19	10,703	375	3.5	4	296,475
City of Gates	20	240,452	7,722	3.2	7	141,331
City of Gold Hill	21	284,023	9,020	3.2	7	654,013
City of Riddle	22	192,494	5,395	2.8	7	521,502
City of Hermiston	23	390,040	10,675	2.7	7	338,577
PP&L-Toketee Village	24	224,206	5,763	2.6	2	139,507
City of Ontario	25	44,355	1,057	2.4	3	196,307

[1] Number of land tenures where fires ignite and burn into the PWS

[2] Largest fire exposure to the PWS

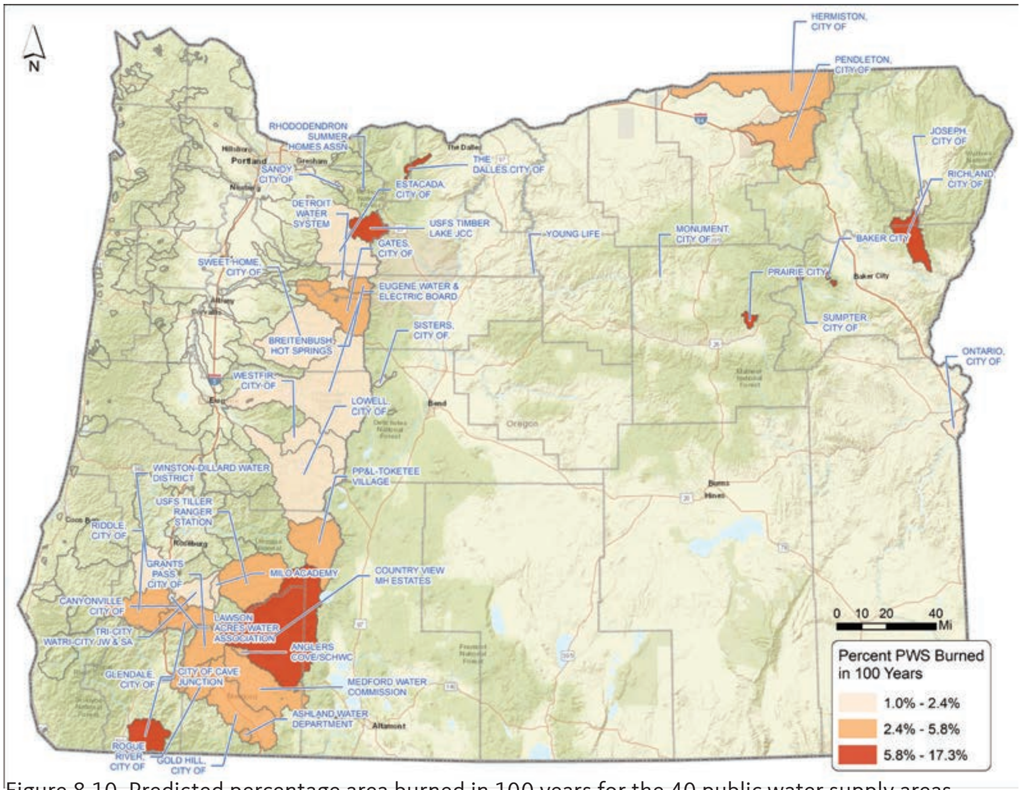


Figure 8-10. Predicted percentage area burned in 100 years for the 40 public water supply areas (PWSA) with highest exposure to wildfires.

numbers are small, wildfire risk often comes from extreme but rare events. The average size of the largest fire over 10,000 simulated fire seasons that burned public water supply areas was 121,314 acres and values ranged from 40 acres for the City of Veronia to 654,013 acres for the City of Gold Hill (Table 8-2).

8.3.3. Predicted wildfire transmission by land tenure

There was high variability among the major land tenures and their contribution to public water supply area wildfire exposure within and among public water supply area regions (Figure 8-11). The U.S. Forest Service (Federal-FS) was the leading contributor to area burned in all but the coastal region where private industrial lands were the largest contributor.

8.3.4. Public water supply area firesheds

Firesheds were generated for each of the 140 public water supply areas that experienced wildfire in our simulations. Firesheds represent the biophysical risk containers in and around public water supply areas and the sources of risk in terms of ownership; they represent areas surrounding each public water supply area that can ignite and transmit large wildfires that expose an individual supply area. Fireshed boundaries can be orders of magnitude larger than the administrative boundary of the supply area and can represent a mosaic of land tenures. As an example, the fireshed of the City of Rogue River public water supply area is 12 times larger (830,000 acres) than the supply area itself with four land tenures as the major sources of exposure (Figure 8-12). Mitigation of wildfire exposure in this example would require the collaborative planning by one federal agency, city/county managers, and representatives of the private and private industrial

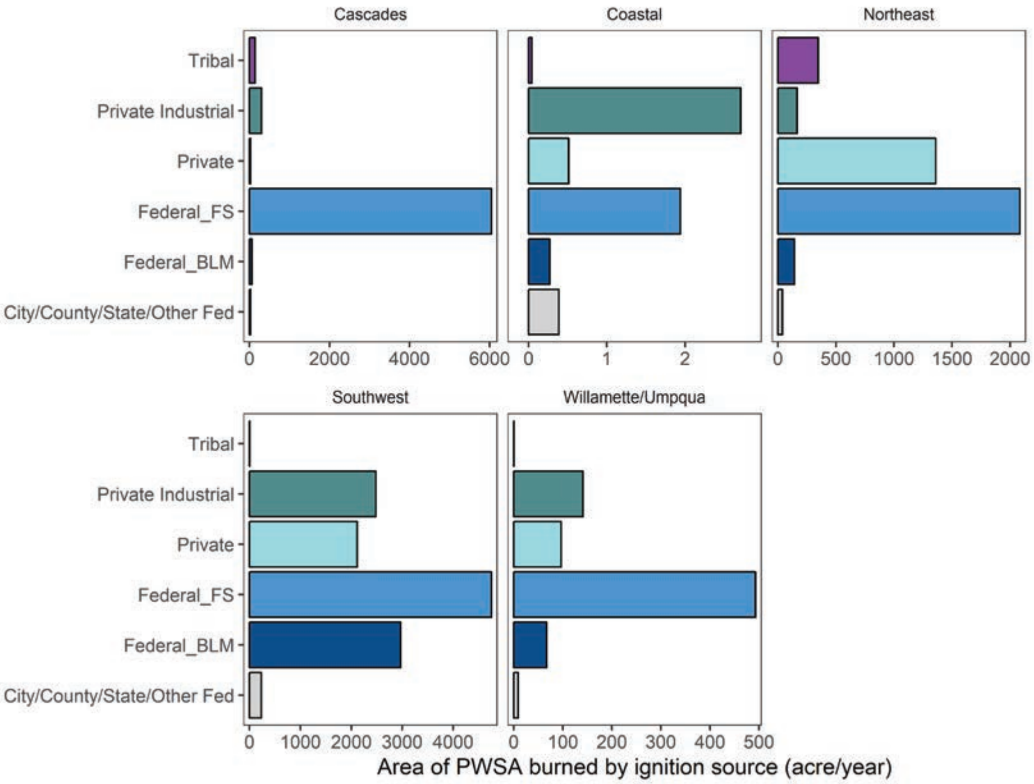


Figure 8-11. Predicted annual area burned by ignition source in public water supply area (PWS) regions. Note the differences in the scale of the x-axis panels.

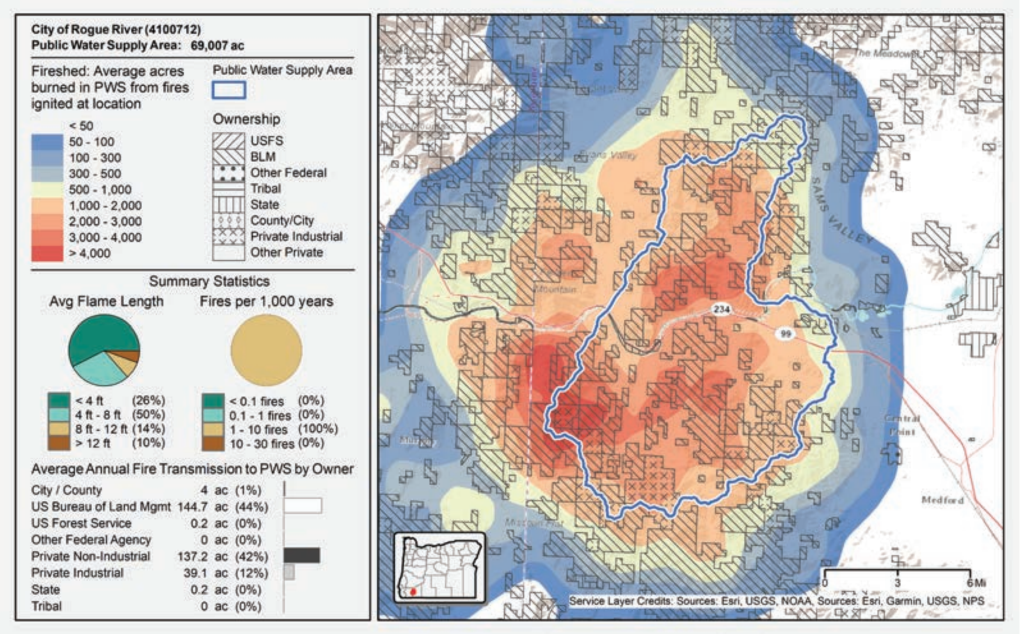


Figure 8-12. Example cross-boundary wildfire analysis results for an individual public water supply (PWS), City of Rogue River. Results for all PWS can be found in an online atlas.

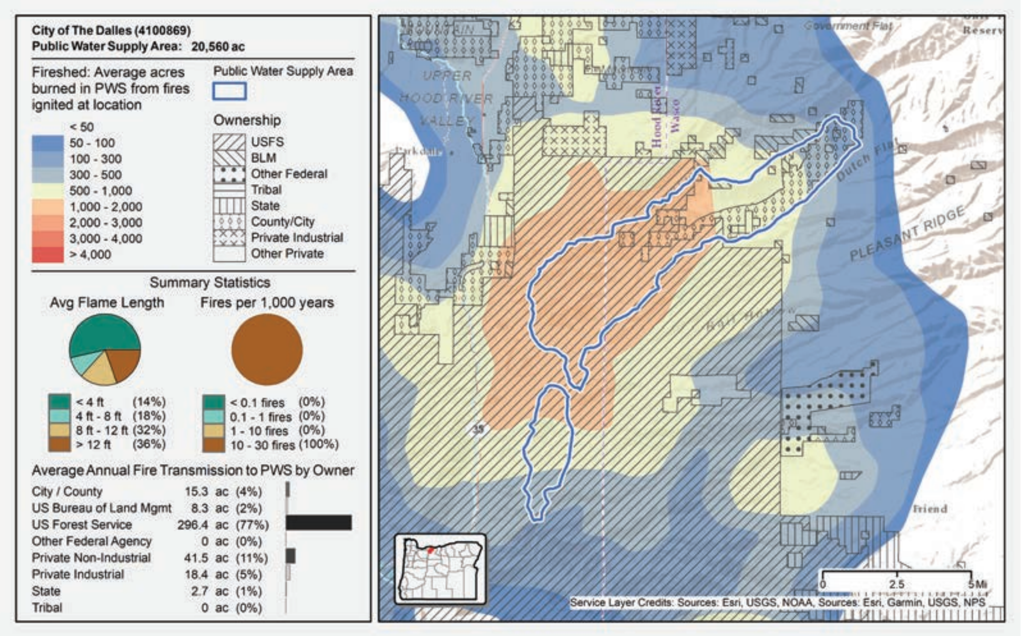


Figure 8-13. Example cross-boundary wildfire analysis results for an individual public water supply (PWS), City of The Dalles. Results for all PWSAs can be found in an online atlas.

communities. In contrast, the fireshed of The Dalles is 22 times larger than The Dalles public water supply area and would require collaborative planning with six land tenures, although 77% of the exposure comes from national forest lands (Figure 8-13).

8.4. Discussion

The juxtaposition of fire prone forests in and around critical municipal watersheds intermixed with a high number of homes and infrastructure, and in close proximity to dense urban areas under a changing climate, creates a complex fuel management problem. Our analysis showed that, while rare, large and severe fire events will continue to occur, especially in the southwest, eastern Cascades and eastern portions of the state, exposing public water supply areas. Our analysis also showed that if forest management has the potential to reduce fuels and restore ecological resiliency, the scale of the risk will require a coordinated, multiagency, multi-landowner collaborative response. Thus, coordinated and targeted fuel management and forest restoration activities that minimize the risk of fire exposure to public water supply areas, maximize landscape resilience to wildfire, and expand decision space for beneficial wildfire management will be needed (Stephens et al. 2016).

Translating the findings in this report to prioritize fuel management activities is straightforward. Maps of fire transmission to public water supply areas can be used as priorities in scenario planning models (Ager et al. 2011, Ager et al. 2017b) to design and sequence project areas and treatment units within them. Including potential treatment costs and revenues associated with harvesting and fuels treatments into planning makes it possible to examine economic costs and benefits associated with forest management to protect water. Optimization models can also be used to locate treatments to address multiple values and risk, including wildfire transmission to the wildland-urban interface, forest health and wildfire risk to other values. Since cost-benefit analyses generally do not show benefits from forest management to water supplies (Gannon et al. 2019), identifying the manifold effects of treatments can help expand the treatment footprints.

Novel tax funding mechanisms used in cities like Ashland and Flagstaff (City of Ashland 2019, FWPP 2019) to fund fuel treatments should take advantage of assessments like that reported here to strategically treat high transmission areas.

Our fireshed maps are also useful for identifying the scale of risk to public water supply areas and determining the relative contribution from different landowners. The scale of risk is typically underestimated in risk reduction planning efforts, and, as fires grow larger under a changing climate, the scale of risk continues to increase. Newer initiatives like shared stewardship (USDA Forest Service 2018) recognizes that the increasing scale of risk requires cross-boundary prioritization and action to treat at the appropriate scale. The core idea in this initiative is to expand land treatments across boundaries to reduce the scale mismatch between wildfire risk and the current forest management footprint. However, the process will require spatial planning to coprioritize projects, meaning that respective federal and state assessments on land conditions (threats and opportunities) will require a multicriteria approach to integrate the respective priorities identified in agency and state assessments and understand trade-offs (Ager et al. 2018). Assessments of cross-boundary risk, such as the work presented here, can be integrated into this process and used as a management objective to target forest management where wildfires are predicted to spread across federal and state boundaries and expose drinking water or other highly valued resources.

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